Senior Thesis

Conodont Biostratigraphy of the Ordovician Bills Creek, Stonington, and Big Hill Formations in the Upper Peninsula of Michigan

By
Michael LaRowe
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Submitted as partial fulfillment of the requirements for the degree of Bachelor of Science in Geological Sciences at The Ohio State University, Summer 2000

Approved by:

Stig M. Bergström

Dr. Stig M. Bergström

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I dedicate this paper to the memory of two late grandpas, Robert L. King and Harold E. LaRowe. They have been a great influence on my life and I thank them very much.

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Abstract

Conodonts from exposures of three Ordovician formations in the Upper Peninsula of Michigan have been investigated. The Richmondian seas show a regressive trend and the rocks in the study area exhibit a change from dominating shale to dominating limestone. The conodont species associations change from a deeper water fauna to a shallower water fauna. Using Sweet's model of conodont biofacies in the Middle and Upper Ordovician of the Cincinnati region, a species association of *Amorphognathus*, *Phragmodus*, and *Plectodina* represents a deeper water fauna and a species association with *Rhipidognathus* a shallower water fauna. The Bills Creek Formation which is the stratigraphically lowest formation I studied, is dominated by *Phragmodus* and *Plectodina*. The Stonington Formation fauna is very similar to that of the Bills Creek Formation with *Phragmodus* and *Plectodina* dominating. The youngest formation studied, the Big Hill Formation, has a very different fauna than those of the other two formations. *Rhipidognathus* dominates and only a few specimens of *Phragmodus* are present, showing a substantial decrease in water depth.

The collections assembled from the Stonington Peninsula are important for dating the formations in terms of standard Ordovician conodont zones. The presence of *Amorphognathus ordovicicus* is an excellent indicator of the Richmondian Stage since it evolved from *A. superbus* shortly after the beginning of Richmondian time. The presence of this species, as well as the rest of the conodont faunas, indicate that the upper Bills Creek, the Stonington, and the Big Hill formations belong in the *A. ordovicicus* zone and

are of Richmondian age. This is in good agreement with evidence from the megafossil faunas but differs substantially from previous age interpretations based on conodonts.

Introduction

The Upper Peninsula of Michigan has a unique set of formations that crop out on and around the Stonington Peninsula. Early studies based on macrofossils indicated that these formations are of Richmondian age. Their isolated geoographic location between the outcrop areas in the Upper Mississippi Valley and the Cincinnati region makes them very interesting. These units are Bills Creek, Stonington and the Big Hill formations. Not much modern information has been available about these formations, and their age has been controversial. The purpose of present study is two-fold: 1) Establish the precise age of the exposed Ordovician succession on the Stonington Peninsula using conodonts; and 2) Examine the biogeographic and biostratigraphic relations of its fossil faunas to equivalent rocks in the Upper Mississippi Valley and the Cincinnati Region.

Geologic History

In the Ordovician the North American continent (Laurentia) was centered on the equator (Scotese and Mckerrow 1990). The Iapetus Ocean and the Tornquist Sea began to narrow, and volcanic arcs were present east of Laurentia (Scotese and McKerrow 1990). During the late Ordovician Gondwana was located south of the equator and extended across the South Pole. The paleolatitude of the Great Lakes in the Late Ordovician was about 20 degrees south. This places this region in the tropics thus providing environmental conditions suitable for carbonate deposition. This applied to the Michigan Basin, which is a relatively shallow intracratonic structure.

The end of the Ordovician was a time of orogeny in eastern North America. The Taconic Orogeny caused the formation of the Appalachian Mountains, the uplift of the Cincinnati Arch and the establishment of the Appalachian Basin. The Canadian Shield borders the Michigan Basin to the north. The Wisconsin Arch and the Cincinnatian Arch are to the west and the south, respectively. The Trans-Continental Arch was a dominating feature in the region west the Upper Mississippi valley.

The Upper Peninsula of Michigan is an important region for the understanding of the regional Upper Ordovician geology of the central Midcontinent. Parts of the uppermost Ordovician succession reflects pulses of deltaic sediments transported from the Taconic Mountains in streams flowing westward (Dorr and Eschman 1970). The Trans-Continental Arch to the west could also have been a source for some of the sediments, if not all. In northern Michigan, the Upper Ordovician is exposed in large outcrops only on the Stonington Peninsula and surrounding area. In these outcrops the rocks have a gentle dip to the east and south.

In the Upper Ordovician, the dominant lithologies are shales, mudstones, and carbonates. These strata represent a clastic wedge west of the newly risen Eastern

Highlands, and they contain largely endemic North American Faunas that have little in common with the faunas in the east (Neuman 1976).

The uppermost Ordovician formations that crop out in the Upper Peninsula of Michigan are the Bills Creek Shale, Stonington and Big Hill Formations (Figure 1). There has been some debate about their exact age of the units in the Upper Ordovician. Hussey (1925, 1952) put these formations in the Richmondian Stage using macrofossil data. Votaw (1980, 1985) dated the three formations as representing the Trentonian, Edenian and Maysvillian using conodont biostratigraphy. Votaw (1980, 1985) used Sweet's (1984) zones of the Middle and Upper Ordovician of the Midcontinent of North America. Other work on these formations includes Rominger (1873), Foerste (1917) and Brandt (1987, 1988).

Stratigraphy

The type section of the Bills Creek Formation is along the north bank of Bills Creek. A total thickness is 67 feet and 4 inches is exposed. This section is about 25 miles northeast of Escanaba in the east half, sec. 12, T.41N, R.21W, and West half, sec.7, T.41 N, R. 20W, Delta County (figure 2). The total thickness of the whole formation is 245 feet in the Cleveland-Cliffs core from Cooks, Schoolcraft County (figure 1), which is 32 miles north-east of Escanaba (Votaw 1980). The rock is a thin bedded, soft shale, with occasional, up to six-inch thick, layers of hard shale. The color of the shale is gray to brown and when weathered, it becomes bluish. Thin layers of argillaceous, fine-grained, limestone are interbedded with the shale. The shale and the limestone grade into each other horizontally.

The section of the Bills Creek Shale at the type locality is mostly shale that is blue in color. There are some beds of argillaceous limestone that are 2-5 inches in thickness. Hussey described this section in 1928.

There are other outcrops of this unit in the area, including along the Soo line railroad cut west of Ensign, in Squaw Creek, and along the eastern shore of Little Bay de Noc. Hussey (1928, 1952) described the top of the Bills Creek Formation in the outcrop one-half mile north of Stratton's farm along the eastern shore of Little Bay de Noc level. This is well exposed at an apparent erosion surface overlain by a conglomerate at the Lakewood Cemetery section just north of the Stonington Community Center (figure 3). However, the limestone bed just above this surface contains numerous pieces of *Isotelus*, including a pygidium oriented almost vertically, and appears to represent an event bed, a tempestite, and is probably a storm or hurricane deposit. Hence, it is uncertian whether or not this surface is a significant unconformity or disconformity or just a local phenomenon. In view of this, and the fact that the overlying three feet of section contain

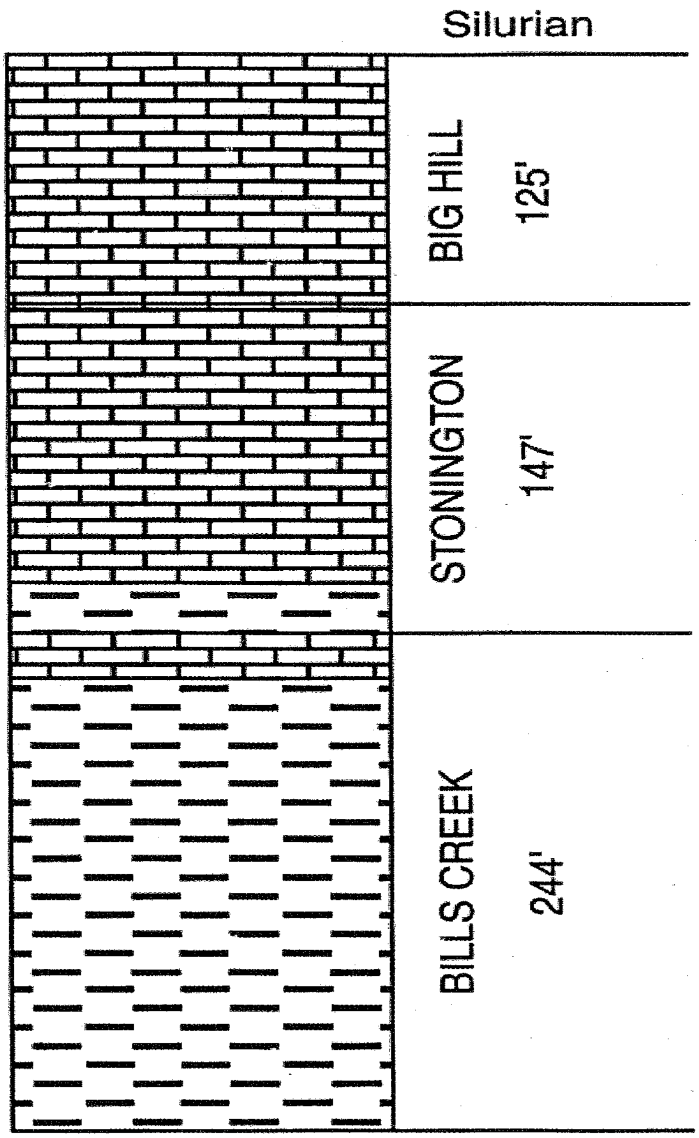
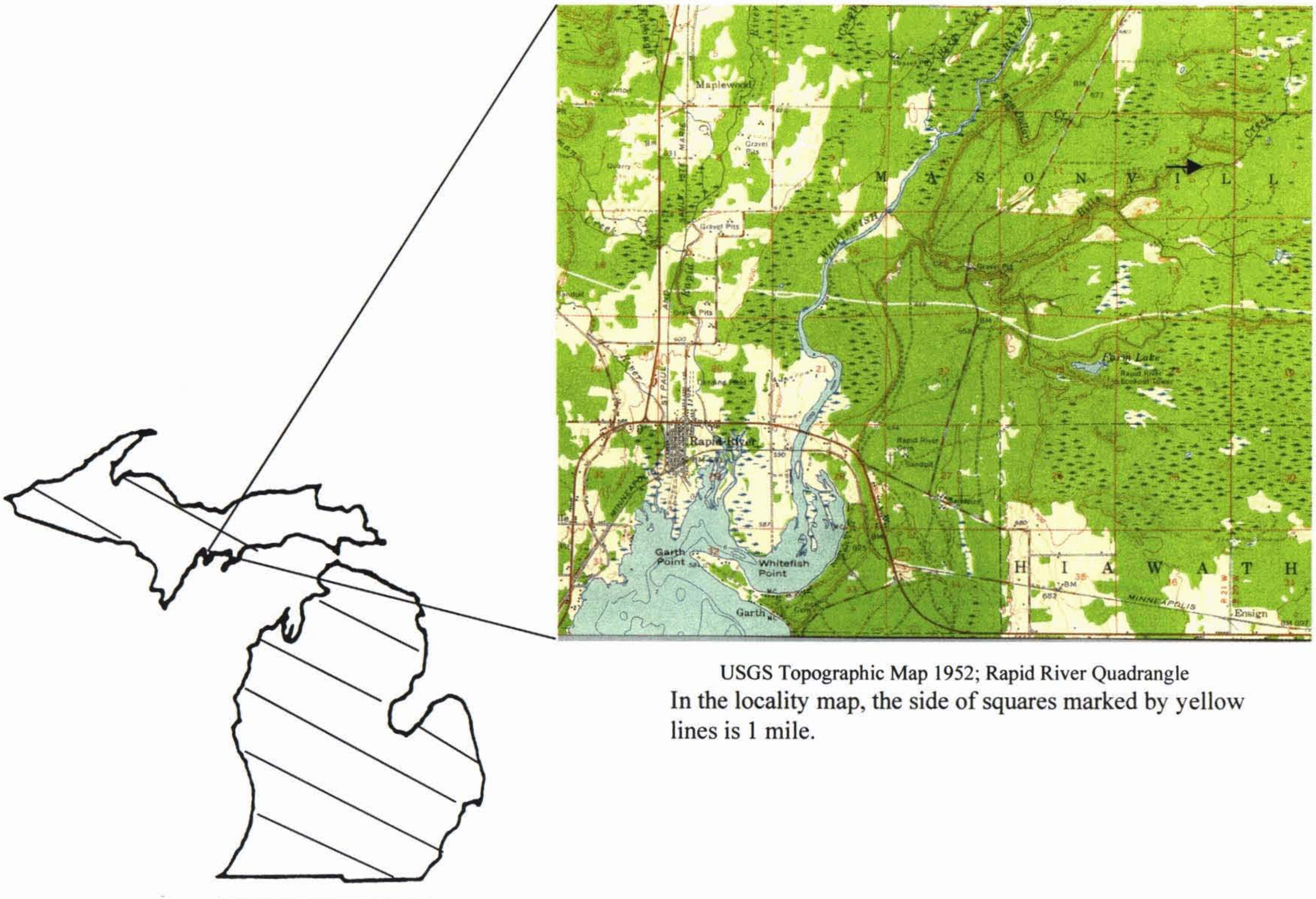


Figure 1. Upper Ordovician formations studied in the Stonington Peninsula region. Thickness are based on the Cleveland-Cliffs Core (Votaw 1980)



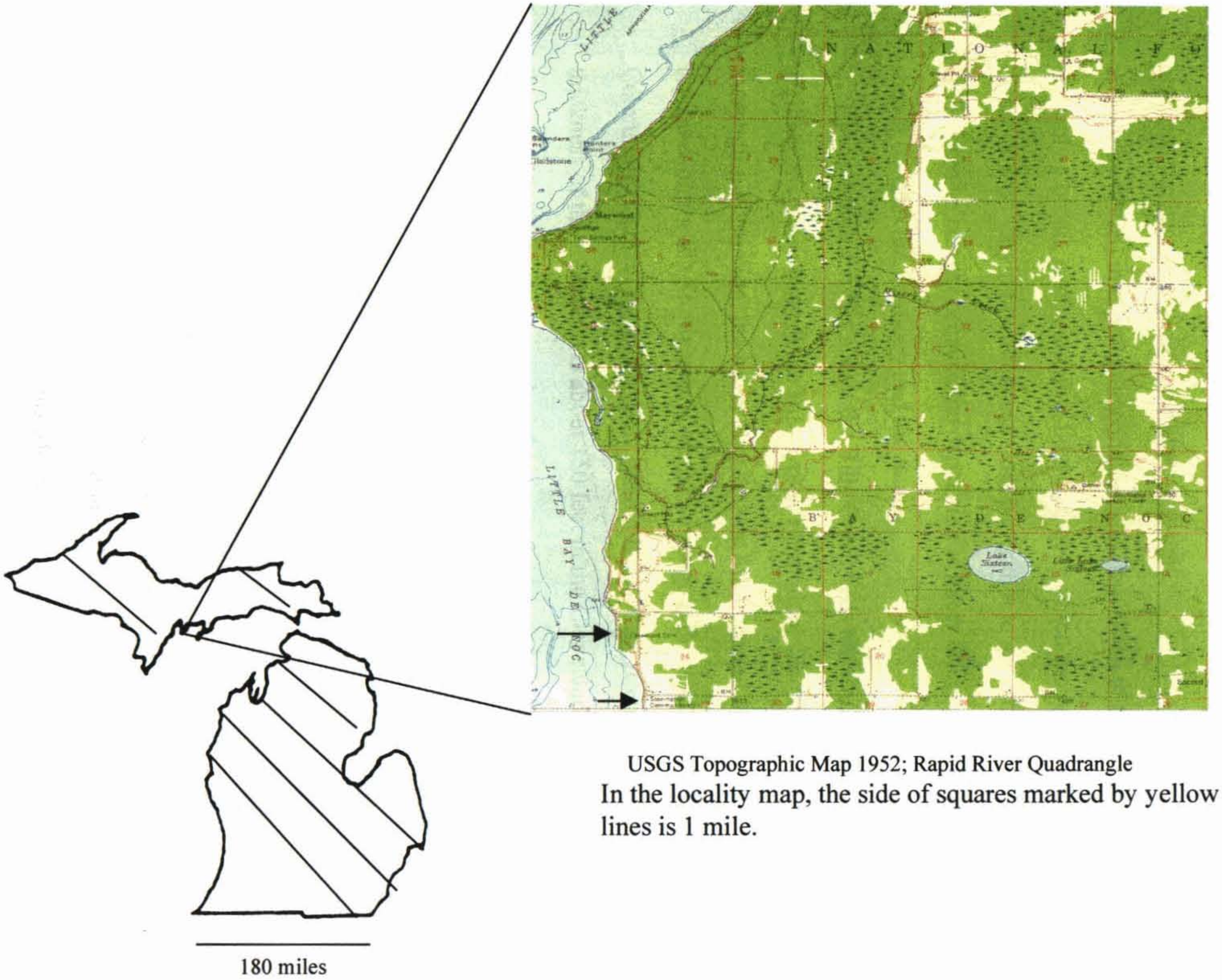
USGS Topographic Map 1952; Rapid River Quadrangle

In the locality map, the side of squares marked by yellow lines is 1 mile.

180 miles

Figure 2. Location (arrow) of the Bills Creek section.

Figure 3. Contact (arrow) of Bills Creek and Stonington formations, Hussey (1952).



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In the locality map, the side of squares marked by yellow lines is 1 mile.

Figure 4. Location (arrow) of Stonington Community Center and Lakewood Cemetery section.

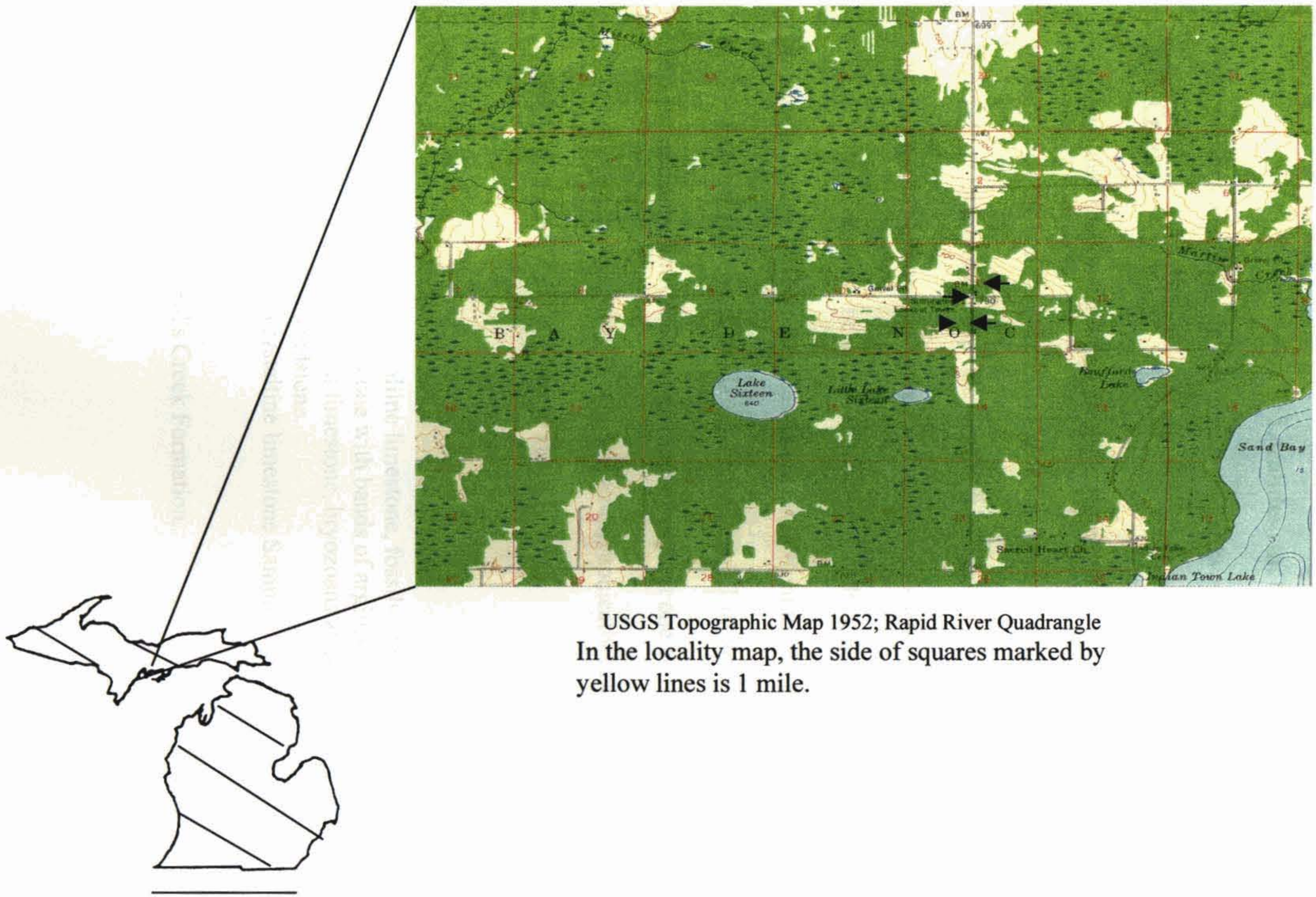
much shale, the omission surface may not be a proper formation boundary useful for mapping regionally and I prefer to place the base of the Stonington Formation three feet higher at the base of a prominent limestone unit.

Hussey (1928) interprted the conditions of deposition of the Bills Creek Shale as probably a broad, gently sloping, tidal flat, over which the water periodically spread layers of mud varying in thickness from paper thin to six inches. This hypothesis is unlikely to be correct because the deposition is likely to be in relatively deep water as shown by both the lithology and the fauna.

The Stonington rocks above the Bills Creek beds are similar in lithology to the argillaceous limestones in the Bills Creek Formation. There are two members within the Stonington Formation, the lower Bay de Noc Member and upper Ogontz Member. The type section for the Stonington is on the Stonington Peninsula just west of the Stonington Community Center (figure 4). This section is 25.6 feet from top to bottom. The total thickness of the formation is about 150 feet in the Cleveland-Cliffs core (Votaw 1980). Foerste (1917) first distinguished these members based on lithic characteristics. The lower member was described as the argillaceous Richmond and the upper member as the cherty Richmond.

The Bay de Noc Member is mostly argillaceous limestone that has a gray or blue color. The amount of shale in this section is decreasing as one moves up stratigraphically. In the section north of Stratton's farm, the lower four feet are argillaceous limestone with interbedding of a few inches of shale. Higher up in the section the member consists of interbedded limestone and shale. The last 6 feet of the member are mostly argillaceous limestone. Some of the beds in the Bay de Noc are very rich in macrofossils. The Ogontz Member differs from the Bay de Noc Member in lacking a great amount of argillaceous limestone. This might be a result of the more clear water at the time of deposition (Hussey 1928). The limestone in this member is soft and some of the basalmost limestone is argillaceous. There are bands or lenses of chert that is white in color. Fossils are very abundant. No great thickness of the Ogontz Member is exposed in outcrop, and there is no outcrop showing the contact between the Stonington and the Big Hill Formations.

The Big Hill Formation (figure 1.) has been distinguished by lithology as well as by fossils it content. It contains the *Calapoecia* fauna, which is characteristic of the widespread invasion of the late Richmondian sea (Ulrich 1911). The total thickness of the formation is 125 feet in the Cleveland-Cliffs core (Votaw 1980). The type section of the Big Hill Formation is at Hinkin's Hill (figure 5). This outcrop shows gently south dipping strata. The bottom part of the section is argillaceous, dark gray, soft to hard, finely grained, somewhat siliceous limestone. Higher up, the limestone is light gray in color, dolomitic, and very fine grained with bedding surfaces covered with shallow pits, which may be worm borings. There are a few poorly preserved casts of pelecypods. Another, and better, outcrop of the Big Hill Formation is the quarry section southwest of the K-10 and 511 road intersection, where there is a 12 feet thick unit of dolomite that is gray in color and an overlying 8 foot thick yellow-weathering dolomite with no megafossils. Votaw (1980) described this section and Brandt, Larcinese, and Anderson (1988) studied the dolomitization of these units. The upper part of the Big Hill Formation is very poorly exposed and no outcrop is known showing the contact with the overlying Manitoulin Dolomite of early Silurian age.



USGS Topographic Map 1952; Rapid River Quadrangle
In the locality map, the side of squares marked by yellow lines is 1 mile.

180 miles

Figure 5. Location (arrow) of the Quarry at the 511 road, and Big Hill Road ditch sections.

Localities studied

Eight sections were investigated during the fieldwork.

Bills Creek

The oldest section stratigraphically exposes part of the Bills Creek Formation. This locality is on the banks of the Bills Creek, northeast of Rapid River (figure 6). On the Rapid River Quadrangle map this locality is located on the edge of the west side of box 7 and the east side of box 12 (figure 2). Two outcrops where sampled (figure 6).

Outcrop A shows 55 inches of 3-5 inch thick beds of brownish-gray crystalline limestone (figure 7). Two samples where taken from this locality. Sample 00B3-1 was taken 19 inches from base, and 00B3-4 was taken 21 inches from the top of the section. This section, apparently the stratigraphically highest one along the creek, is one hundred yards upstream from locality B, which is stratigraphically lower than locality A. A description of Locality B is given in Table 1

4	inches	Brown shale.
4	inches	Gray crystalline limestone, fossils present. Sample 00B3-2.
16	inches	Gray mudstone with bands of argillaceous limestone.
0.6	inches	Gray-brown limestone, bryozoans abundant.
16	inches	Gray mudstone.
3	inches	Gray crystalline limestone Sample 00B3-3.

Table 1. Outcrop B of Bill's Creek Formation.

Figure 6. Section at Bills Creek.

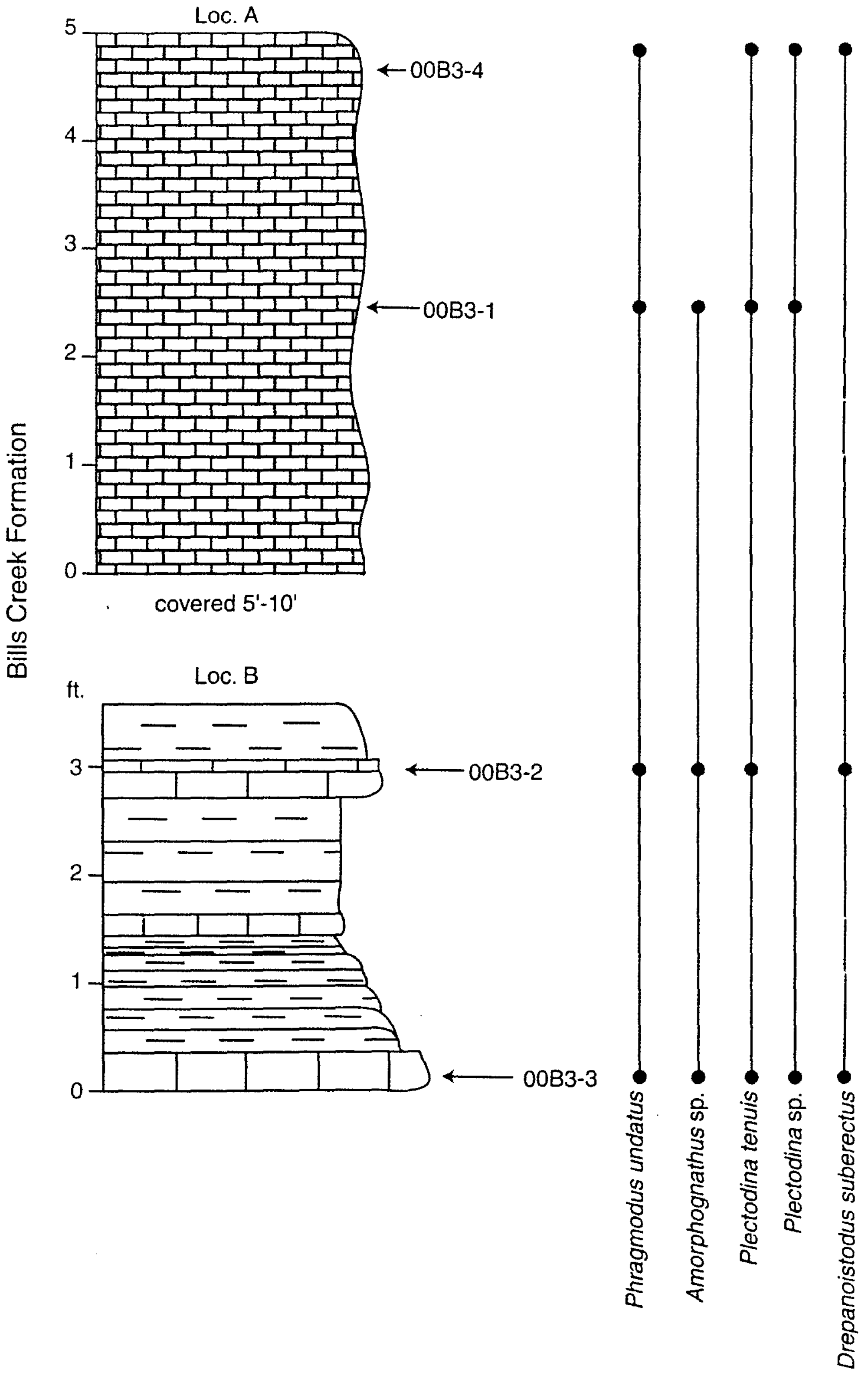


Figure 7. Stratigraphic section at the Bills Creek locality.

Figure 8. Locality at Lakewood Cemetery.

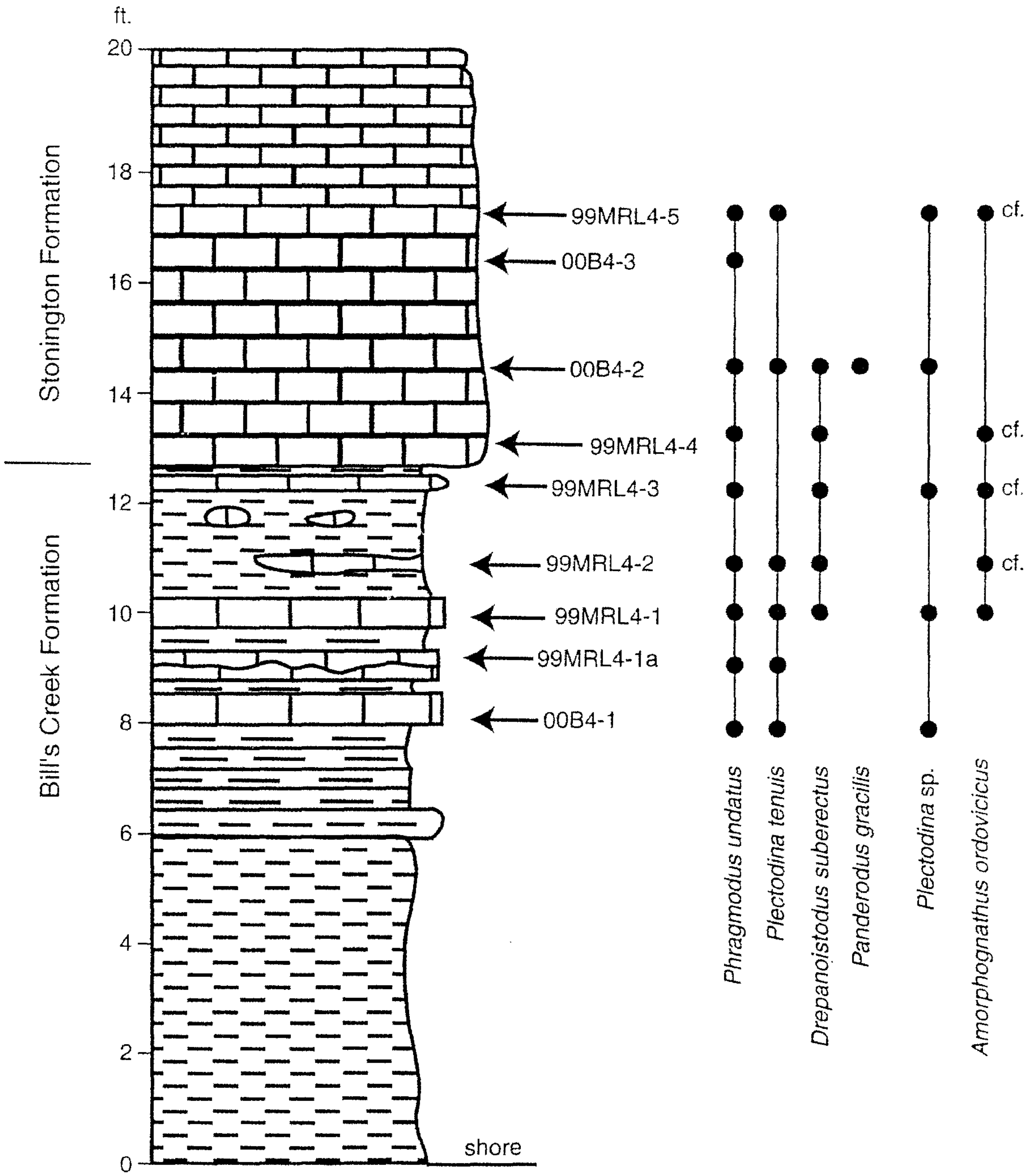


Figure 9. Stratigraphic section of the Lakewood Cemetery.

Figure 10. The Stonington Community Center locality

Lakewood Cemetary

This locality is on the west shore of the Stonington Peninsula 0.25 mile north of the Lakewood Cemetary (figure 8). As noted above, when Hussey (1928) described this section, he placed the contact between the Bills Creek and Stonington Formations at an erosional surface (figures 3, 9). Here, it is placed about 3 feet higher, at the base of a package of limestones that are very different lithologically from the Bills Creek Formation. The section measured is described in Table 2.

7 feet	Tan limestone thick bedded at the base and thin bedded at top of section. Samples 99MLR4-5, 99MLR4-4, 00B4-3, and 00B4-2. Stonington Formation contact at base.
2 feet	Mudstone with pinching layers of limestone, samples 99MLR4-2 and 99MLR4-3.
6 inches	Tanish-gray limestone, fine grained. Sample 99MLR4-1.
6 inches	Dark gray mudstone.
2 inches	Gray limestone, crystalline with *Isotelus* hypestome fragments. Sample 99MLR4-1a.
4 inches	Gray limestone, fine grained.
2 inches	Gray mudstone.
5 inches	Gray limestone, very fossiliferous with *Isotelus* fragments, Sample 00B4-1.
17 inches	Light gray mudstone. Samples 00B4-2,00B4-3.
4 inches	Light gray mudstone, laterally continuous marker bed.
6 feet	Gray mudstone, one foot thick beds.

Table 2. Lakewood Cemetery section.

Only the lowermost part of the Stonington Formation is exposed at the Lakewood Cemetery section. This formation is split into two members, the Bay de Noc Member and the Ogontz Member. The lower seven feet of the Bay De Noc Member is exposed at the Lakewood Cemetery.

Stonington Community Center

A shore section just west of the Stonington Community Center exposes most of the Bay de Noc Member and the lower part of the Ogontz Member (figures 10,11). The contact between these members appears conformable. The section is described in Table 3.

6 feet	Tan limestone in 5 inch thick beds. Sample 99MLR3-8. Ogontz Member contact at base.
9.1 feet	Gray mudstone in basal part, limestone beds in upper part Samples 99MLR3-5, 99MLR 3-6, and 99MLR3-7.
2 feet	Gray limestone, beds 6 inches thick. Sample 99MLR3-4.
6.5 feet	Gray mudstone with interbedded layers of limestone.
2.5 feet	Gray limestone, thin bedded. Samples 99MLR3-1 and 99MLR3-2.
3 feet	section covered by shore drift.

Table 3. Stonington Community Center section.

Delta County Road Commission Quarry at Big Hill

There is no known outcrop on the Stonington Peninsula where the Stonington/ Big Hill contact is exposed but a good Big Hill section is in the quarry just south of the K10/ 511 road intersection (figures 5, 12, 13). The total exposed thickness is 20 feet. The basal 12 feet are gray weathered dolomite mudstone in beds less than one foot thick from which samples 00B6-1, 00B6-2, 00B6-3, and 00B6-4 were taken. The upper eight feet in the quarry wall consist of thick-bedded yellow weathering dolomite (figure 12). From this unit samples 99MLR5-1, 00B6-5, and 00B6-6 were collected.

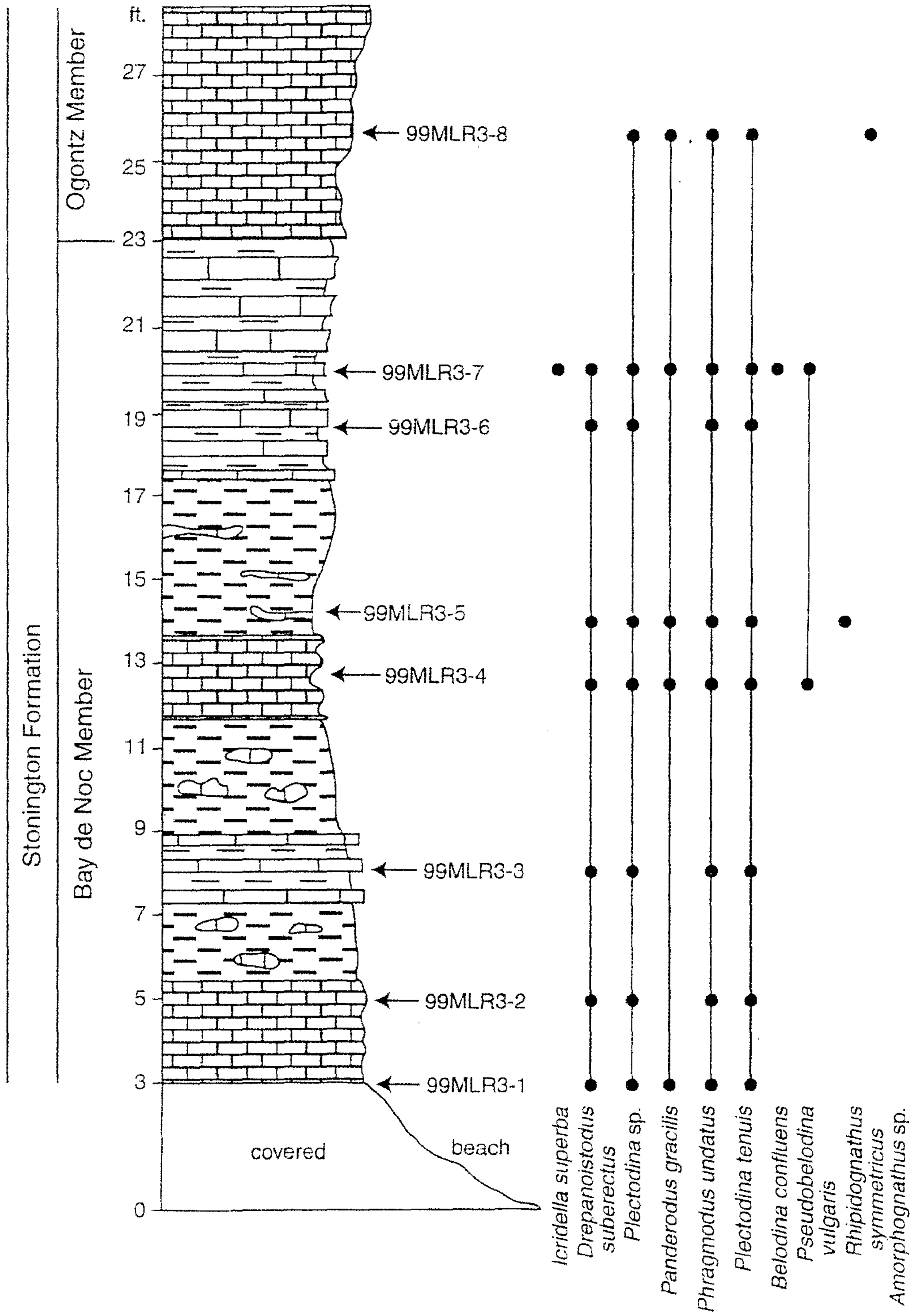


Figure 11. Stratigraphic section at Stonington Community Center.

Road 511 outcrops

Just north of the quarry entrance, there are sufaces of Big Hill exposed in the road ditches. These represent a stratigraphically higher level than the quarry section. Sample 00B7-1 was taken from the rock surface just south of house with the number 6604.

The next locality is a few hundred yards north of the quarry entrance, about 50 meters south of the K10 / 511 road intersection. Sample 00B8-1 was collected in the western road ditch at this locality. The rock is gray limestone with some fossils present. This sample represents a high level in the Big Hill Formation.

Wisley Bay

There are limestone outcrops along the northeast side of the Wisley Bay (figures 14,15,16). The best exposure of the Big Hill Formation is five feet six inches in height (figure 15). The thin-bedded limestone is very fossiliferous. A gray weathered limestone bed (00B5-1) was sampled at the middle of the outcrop (figure 16).

Ensign

A poor limestone outcrop, now almost overgrown, is along the railway 1.5 miles west of Ensign (Votaw 1980). The sample 00B9-1 was taken at one foot above the base of cut.

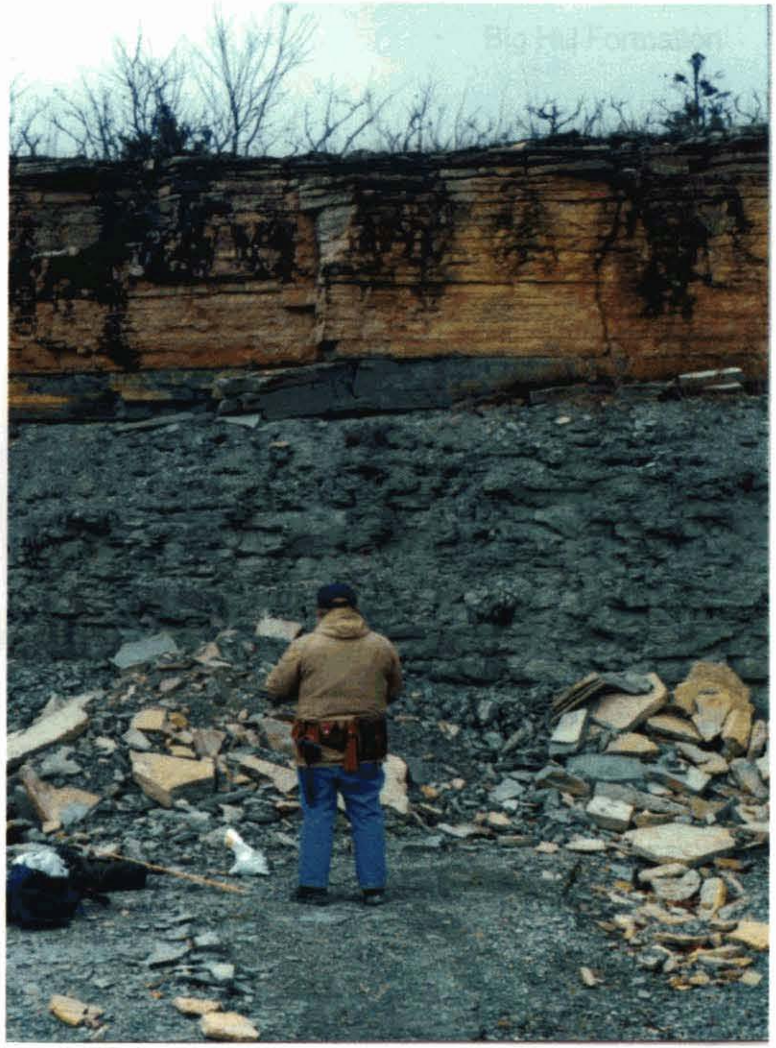


Figure 12. Quarry section northwest of the intersection of K10 and 511.

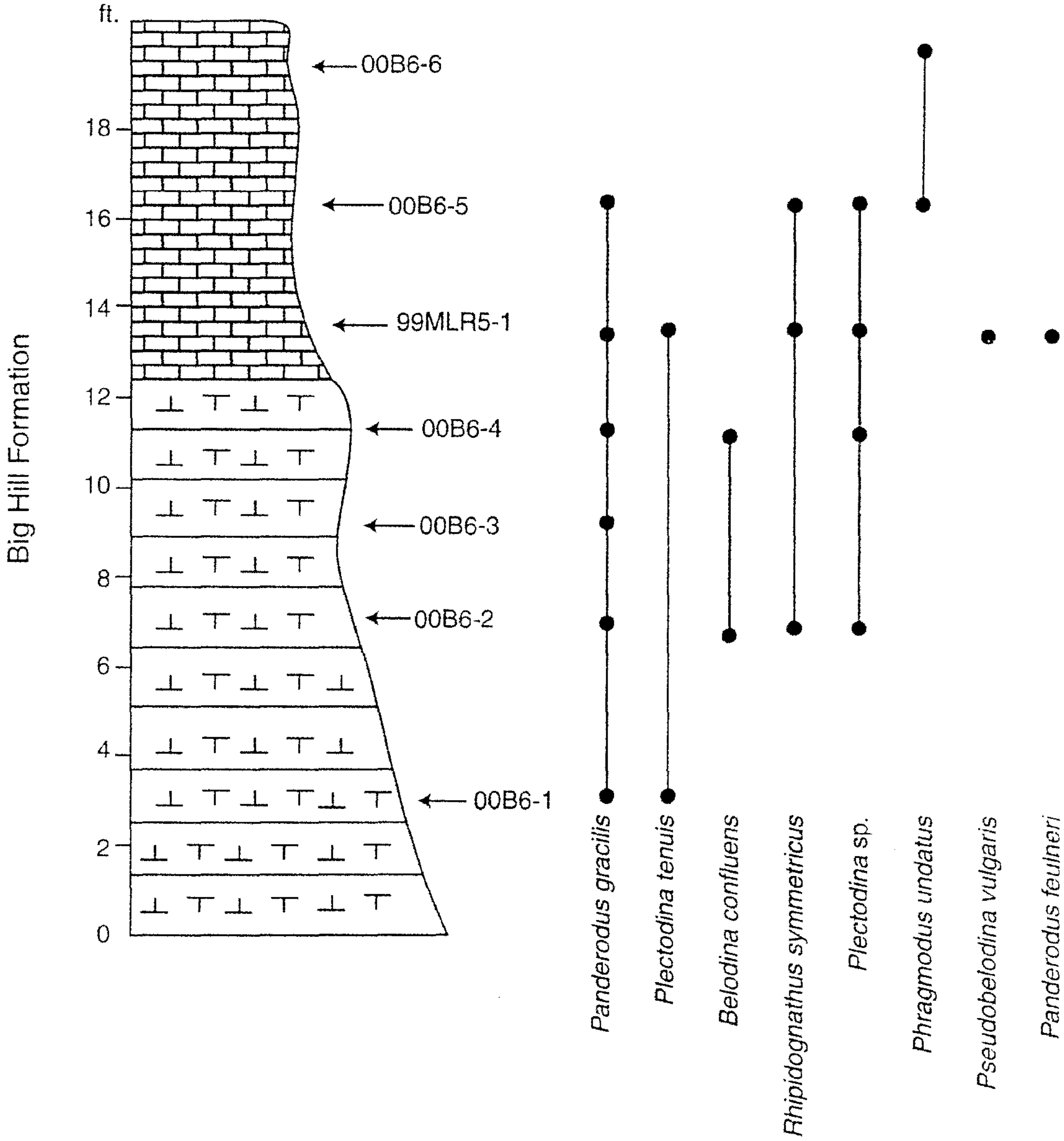
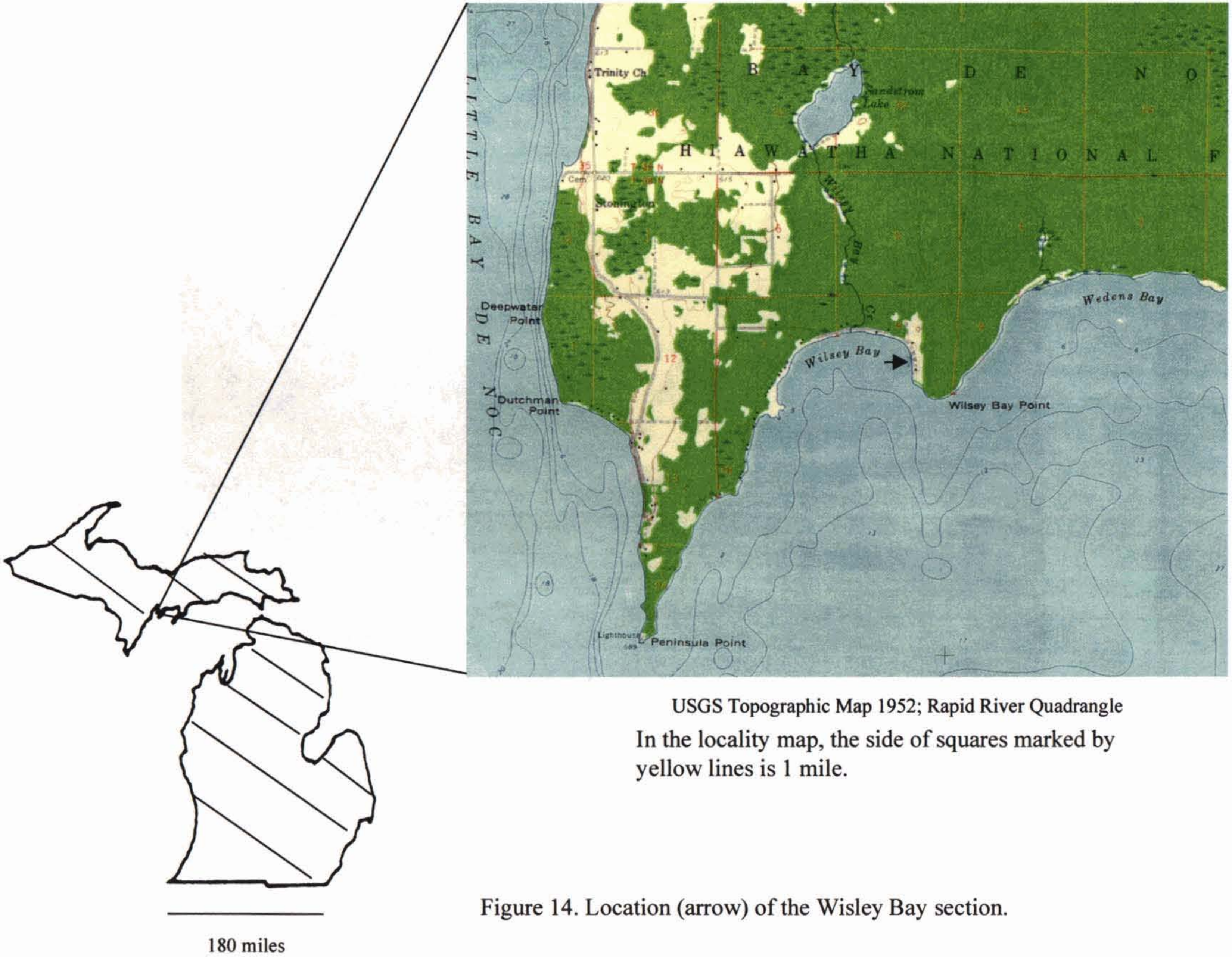


Figure 13. Quarry section near the 511 road, Stonington Peninsula.



USGS Topographic Map 1952; Rapid River Quadrangle

In the locality map, the side of squares marked by yellow lines is 1 mile.

Figure 14. Location (arrow) of the Wisley Bay section.

Figure 15. Section at Wisley Bay.

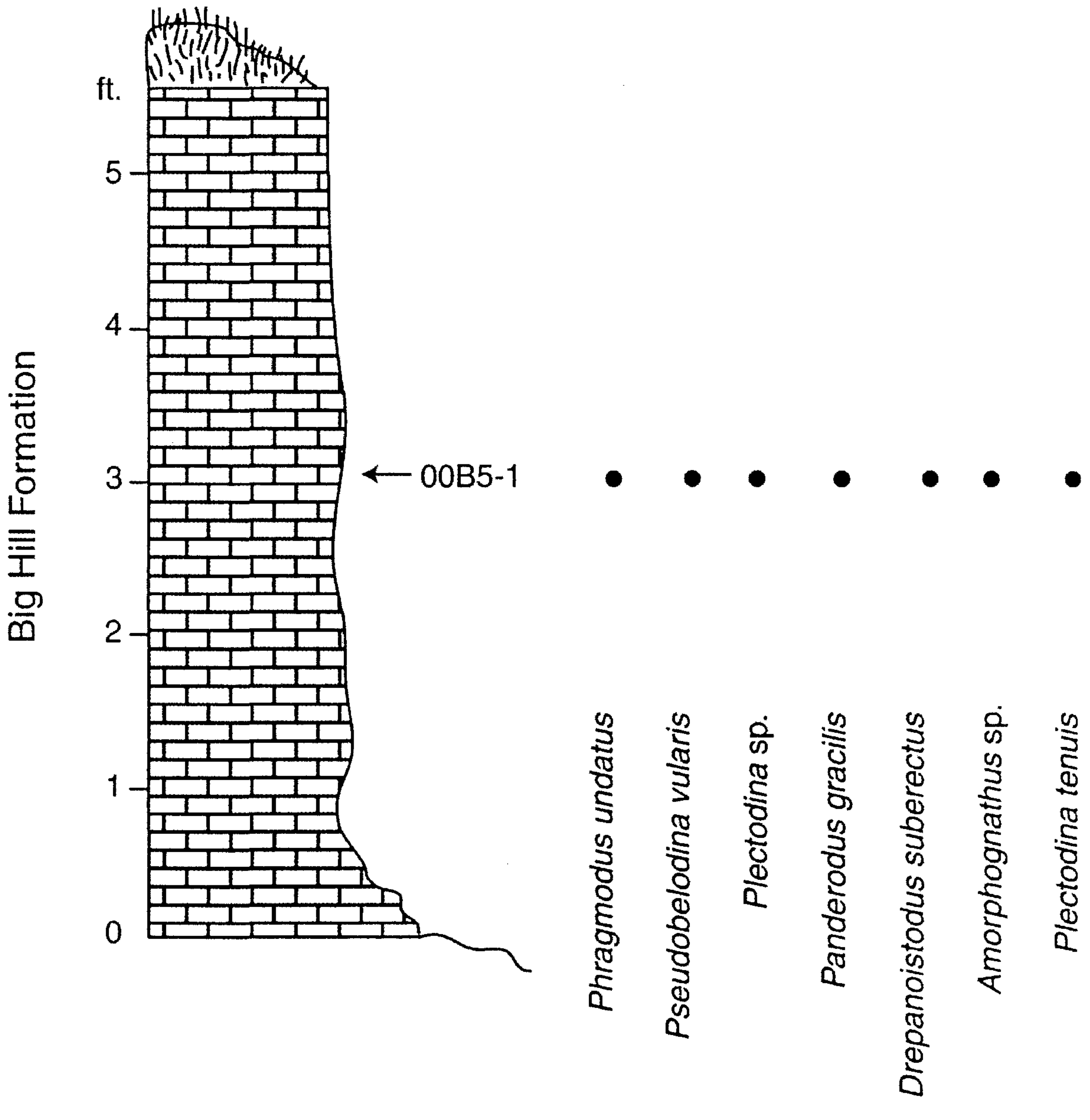


Figure 16. Stratigraphic section at Wisley Bay.

Laboratory Methods

The rock samples were crushed by a rock crusher into one-half to one-quarter inch pieces. One-kilogram samples were used but some samples were processed twice. The rock pieces were placed in a bucket with water and 800 milliliters of glacial acetic acid. The acid was replaced two or three times depending on the amount of rock dissolved. After acid treatment for a few days the samples were washed in water using an 150-sieve tray. The leftover and dried residue was then seperated in heavy liquid tetrabromoethane. The heavy residue was then washed with acetone and dried. The sample then was picked with a 00000 Spotting Sable paint brush and mounted on a paleontological slide for identification. The Magnetic Separator was used for some samples that required the removal of magnetic minerals. From the samples collected a total of 1427 conodont elements were recovered. All elements have a color alteration index (CAI) of 1 indicating minimal heating after burial. Stratigraphic ranges of conodont species at each study section are shown in Figures 7,9,11,13 and 16. Figured specimens with OSU munbers are housed in the type collection of the Orton Geological Museum at the Ohio State University. The rest of the collection is deposited in the Micropaleontological Collections at the Department of Geological Sciences at the same university.

Conodont Paleoecology and Biostratigraphy

Depositional Environment

Conodonts of the Upper Ordovician have been studied in several regions of the Midwest, particularly the Upper Mississippi Valley (Glenister 1957; Webers 1966) and the Cincinnati region (Sweet 1979). Both the paleoecology and biostratigraphy of Upper Ordovician Midcontinent conodonts are now rather well known. Sweet (1988) has developed a depth stratification model for the Upper and Middle Ordovician conodonts in this region. Using this model suggests that the sequence of the three formations in the Stonington Peninsula region represents a shoaling upwards sequence (figure 17).

The Bills Creek Formation is the oldest formation studied. At its type section, the conodont fauna is dominated by *Phragmodus undatus* and *Plectodina tenuis*. Other species are *Amorphognathus* sp., *Drepanoistodus suberectus*, and *Panderodus gracilis*. A similar species association is present in the uppermost part of the Bills Creek at the Lakewood Cemetery The key species *Amorphognathus ordovicicus* occurs close to the boundary between the Bills Creek Formation and the Stonington Formation. In Sweet's (1988) conodont biofacies model faunas of this type occurred in deep to moderately deep water (figure 17).

In terms of conodont biota, the Stonington Formation is very similar to the Bills Creek Formation. Both the Bills Creek and Stonington Formations were deposited in a low energy, offshore, normal marine environment (Wicander and Playford 1999). *Plectodina* sp., *Plectodina tenuis*, and *Phragmodus undatus* dominate the conodont fauna of the Stonington Formation (figures 9,11).

The conodont fauna of the Big Hill Formation is very different from the faunas of the two older formations. The samples from the quarry just south of the K10/ 511 road intersection lack *Phragmodus undatus* but have *Pseudobelodina* and *Rhipidognathus* (figure 13). Based on Sweet's model (figure 17), the abundance of *Rhipidognathus symmetricus* in these samples indicates that the sea had shallowed substantially which is in agreement with the lithologic and macrofossil evidence. Hence, these three formations show a clear trend of shoaling upward stratigraphically. A similar trend can be recoqnized in equivalent rocks elsewhere in the Midcontinent, for instance, in the Cincinnati region.

Biostratigraphy

By far the most important conodont element for dating the section studied is *Amorphognathus ordovicicus.* This species is part of an evolutionary lineage and has been used as a zone indicator by Bergström (1971), and subsequent authors. In the Midcontenent standard succession in the Cincinnati region, this species first appears in the uppermost Arnheim Formation in strata of early, but not earliest, Richmondian age (MacKenzie 1993). A typical specimen of its holodontiform or M element (Plate 1:6) was found at 4 feet 10 inches above the base of the Lakewood Cemetery section. This indicates that the uppermost Bills Creek Formation is of Richmondian age and not Edenian-Maysvillian as proposed by Votaw (1980, 1985). The two overlying formations are also Richmondian which is in good agreement with the evidence of the macrofossils (Hussey 1926). This is also consistent with the interpretation of the age of the Bills Creek Formation based on graptolites,which was recently published by Goldman and Bergström (1997).

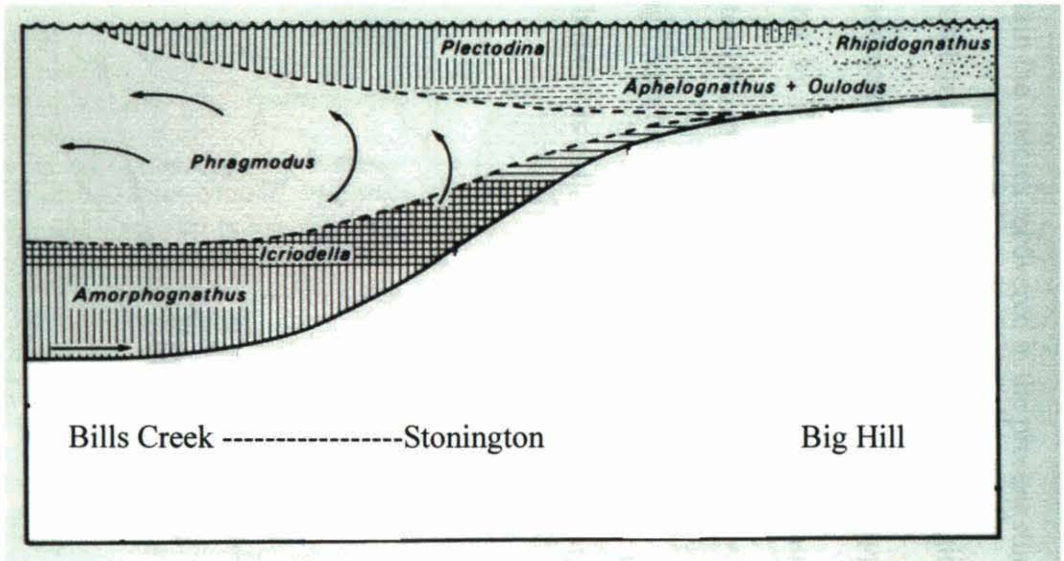


Figure 17. Sweet's (1988) Cincinnatian biofacies model applied to the Upper Ordovician Bills Creek, Stonington, and Big Hill formations.

Faunally, but less so lithologically, the Upper Ordovician rocks of the study area are very similar to coeval rocks of the Cincinnatian region. Virtually all of the Stonington Peninsula conodont species are also known from the Cincinnati region where they typically occur in rocks of the Richmondian Stage. The diverse Upper Ordovician conodont faunas of the Upper Mississippi Valley in Minnesota, Iowa, Wisconsin, Illinois, and Missouri also contain the species recovered in the present study. There is no doubt that the Richmondian stratigraphic interval in the Stonington region has its equivalents in the Dubuque-Cape-Maquoketa succession in the Upper Mississippi Valley. This similarity was recognized by Votaw (1980, 1985) but his correlation with the Cincinnati standard section is quite different from that advocated herein (figure 18). Votaw's (1980, 1985) Cincinnatian stage correlation is in serious conflict with evidence from shelly fossils and graptolites but this is not the case with the revised stage correlation proposed in the present study.

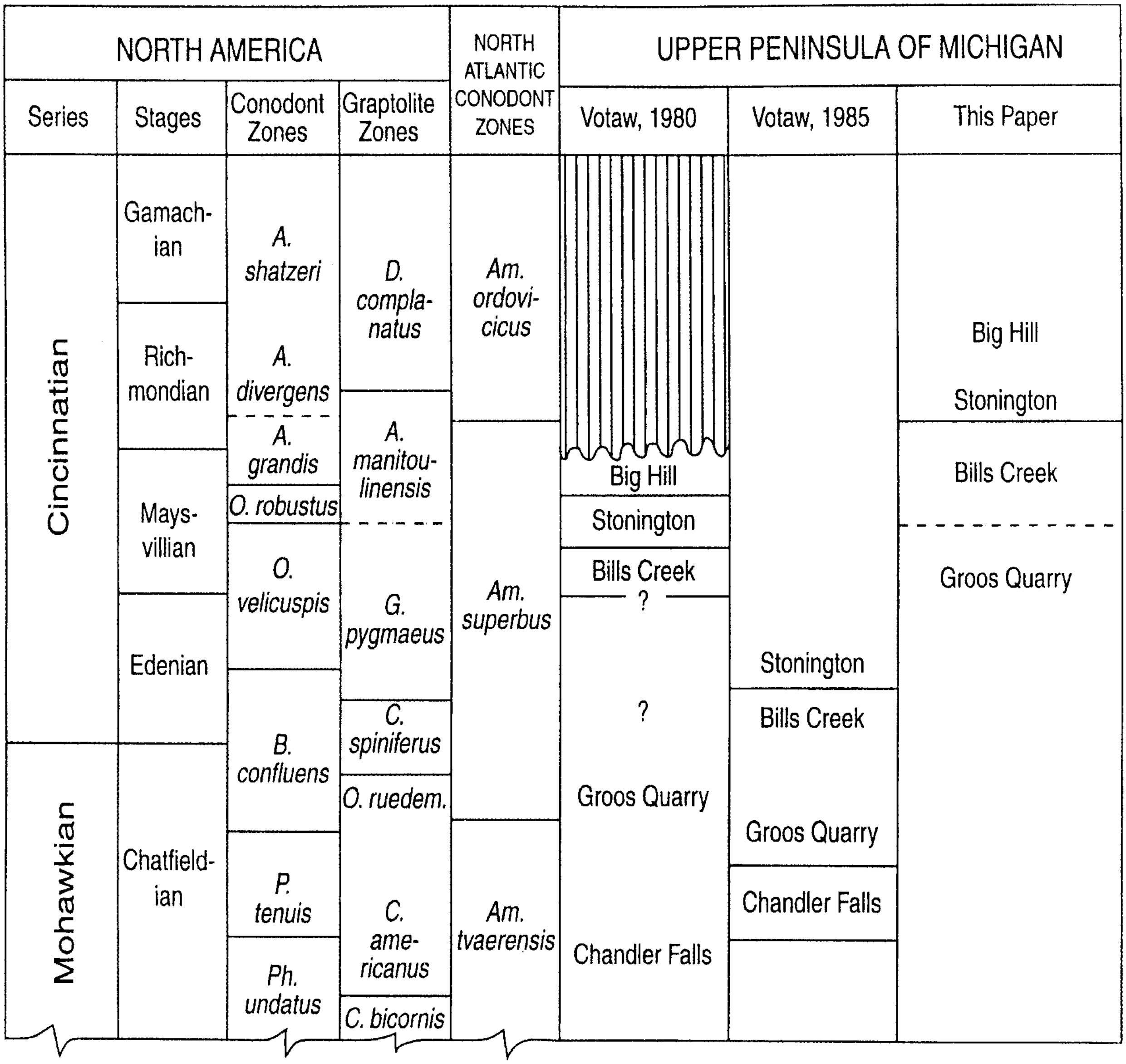


Figure 18. Revised correlation of the units studied compared with Votaw's (1980, 1985) interpretations.

Conclusions

Probably because of their somewhat remote location away from major universities, the three formations exposed on and around the Stonington Peninsula of Michigan have been studied very little compared with coeval units in the Cincinnati region and the Upper Mississippi Valley. Lithologically, the Bills Creek Formation is dominated by thick dark brown shale units in the lower part and gray shale with the increasing interbedding of argillaceous limestone in the upper part. The Bills Creek is disconformably overlain by the Stonington Formation, which has two members. The Bay de Noc Member includes mudstone and argillaceous limestone and the Ogontz Member is characterized by limestone with layers or nodules of chert. The uppermost formation studied is the Big Hill Formation that consists of dolomitic limestone and mudstone containig a distinctive fauna. The conodont fauna of the Bills Creek and Stonington Formations is dominated by *Phragmodus undatus,* and *Rhipidognathus symmetricus* is common in the Big Hill Formation. These elements provide useful information about the environment at the time of deposition. Sweet's (1988) biofacies model based on the Upper and Middle Ordovician in the Cincinnati region can be applied to the Stonington succession (figure 17). Based on this biofacies model, the Bills Creek and Stonington faunas are interpreted to represent deeper-water environments and that of the Big Hill is considered to be a shallow water fauna (figure 17).

The appearance of the *Amorphognathus ordovicicus* in the uppermost Bills Creek Formation indicates the *A. ordovicicus* Zone and an early, but not earliest, Richmondian age for the upper Bills Creek. Based on both conodonts and macrofossils, the overlying Stonington and Big Hill Formations are also considered to be of Richmondian age.

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PLATE 1

1-5 *Amorphognathus* sp.
- 1,3,4 Pa element, sample 00B3-2, x75. OSU 50431.
- 5 Pb element, sample 00B4-2, x80. OSU 50432.
- 2 Sp element, sample 00B3-4, x70. OSU 50433.

6-7 *Amorphognathus ordovicicus* Branson and Mehl, 1935
- 6. Holodontiform (M) element, sample 99MLR4-1, x70. OSU 50434
- 7. Ramiform (Sa) element, sample 99MLR4-1, x75. OSU 50435.

8-10,12 *Plectodina tenuis* (Branson and Mehl, 1933)
- 8. Sa element, sample 00B4-2, x70. OSU 50436.
- 10. Pa element, sample 99MLR3-4, x65. OSU 50437.
- 12. Sc element, sample 00B5-1, x70. OSU 50438.

9,11,13 *Plectodina* sp.
- 9. Pa element, sample 00B8-1, x65. OSU 50439.
- 11. Sc element, sample 00B5-1, x65. OSU 50440.
- 13. Pb element, sample 99MLR3-3, x70. OSU 50441.


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PLATE 2

1 *Plectodina* sp.
1. Pb element, sample 00B4-2, x65. OSU 50442.

2-3,5 *Phragmodus undatus* Branson and Mehl, 1933
2. M element, sample 00B5-1, x65. OSU 50443.
3. Pa element, sample 99MRL4-2, x65. OSU 50444.
5. Sc element, sample 99MLR4-1, x75. OSU 50445.

4 *Drepanoistodus suberectus* (Branson and Mehl, 1933)
Nongeniculate element, sample 99MLR3-1, x70. OSU 50446.

6 *Panderodus feulneri* (Glenister, 1957)
Costate element, sample 99MLR5-1, x90. OSU 50447.

7 *Rhipidognathus symmetricus* Branson, Mehl, and Branson, 1951
Alate element, sample 99MLR5-1, x55. OSU 50448.

8 *Icriodella superba* Rhodes, 1953
Pb element, sample 00B8-1, x50. OSU 50449.

9 *Panderodus gracilis* (Branson and Mehl, 1933)
Tortiform (M) element, sample 99MLR3-7, x80. OSU 50450.

10 *Belodina confluens* Sweet, 1979
Grandiform element, sample 99MLR5-1, x65. OSU 50451.

11 *Pseudobelodina vulgaris* Sweet, 1979
S element, sample 00B8-1, x60. OSU 50452.

12 *Plegagnathus nelsoni* Ethington and Furnish, 1959
S element, sample 00B4-1, x60. OSU 50453.


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